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Progress Towards the Synthesis of Iron-Based Hydrogenation Catalysts Using Hydroxypyridine Bidentate and Tetradentate Ligands

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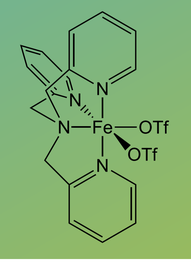


Pharmaceutical Industry & Green Chemistry

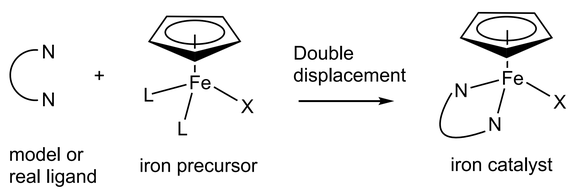
- The pharmaceutical industry is the most wasteful chemical industry, mainly due to the molecular complexity
- Catalysts can help reduce waste and increase the sustainability of chemical reactions
- Hydrogenation is a highly utilized reaction in the pharmaceutical industry
- Current hydrogenation catalysts rely on expensive and harmful metals: Rh, Ir, and Ru
- Iron is a cheaper and a more environmentally benign choice for hydrogenation catalysis

Research Objectives

- The overall objective of this project is to synthesize iron-based hydrogenation catalysts that would replace current transition metal catalysts
- All catalysts will include a hydroxypyridine ligand as a key element of design
- Continue study of bidentate ligands and initiate the study of tetradentate ligands
- Form iron precursor complexes on which to attach the ligands
- Attach model and catalytic ligands to iron precursor complexes
- Test the hydrogenation reactivity of ligand-iron complexes

Bidentate Ligand Attachment to Iron

- Model ligands, bipyridine and DPPE, were used to test conditions for attaching catalytic ligands (Scheme 1)



Scheme 1. Double displacement of model ligand with catalytic ligand

- DPPE attachment in acetonitrile was successful (Figure 1)

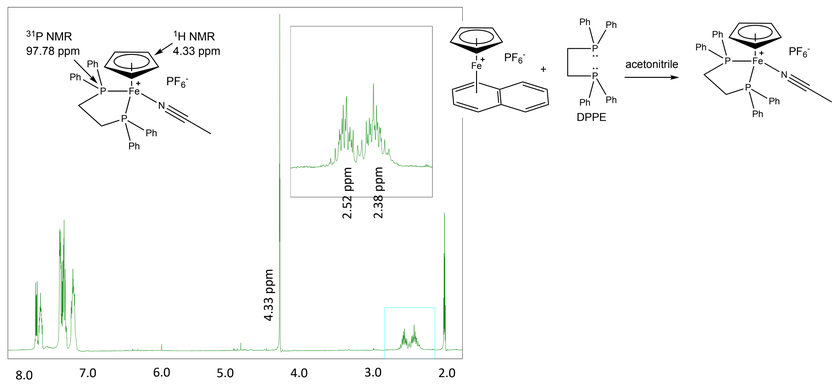
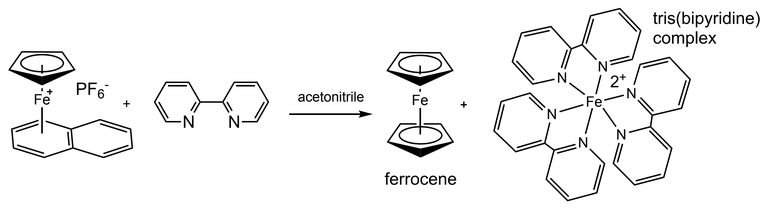


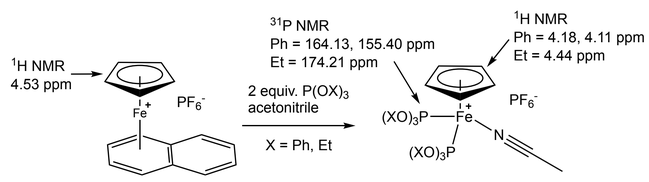
Figure 1. DPPE-iron complex

- Bipyridine attachments tested in six solvents were all unsuccessful either due to solubility or formation of ferrocene and tris(bipyridine) complex (Scheme 2)



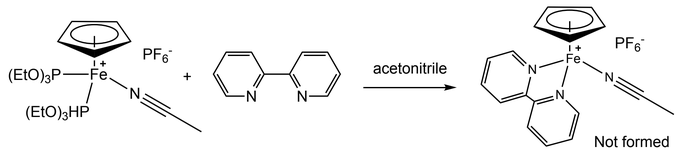
Scheme 2. Formation of ferrocene and tris(bipyridine) complex

- Formed precursor Fe-phosphite complexes to test model ligand attachment (Scheme 3)



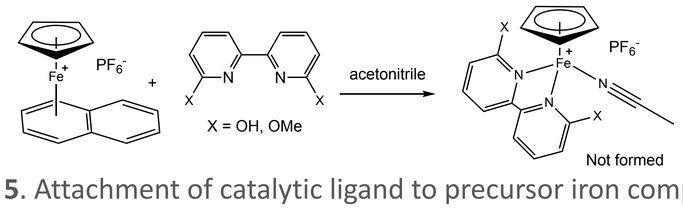
Scheme 3. Formation of iron-phosphite complexes

- Bipyridine attachment with iron-phosphite complexes did not produce a clear NMR spectrum – results were inconclusive (Scheme 4)



Scheme 4. Double displacement reaction between triethylphosphite-iron complex and bipy.

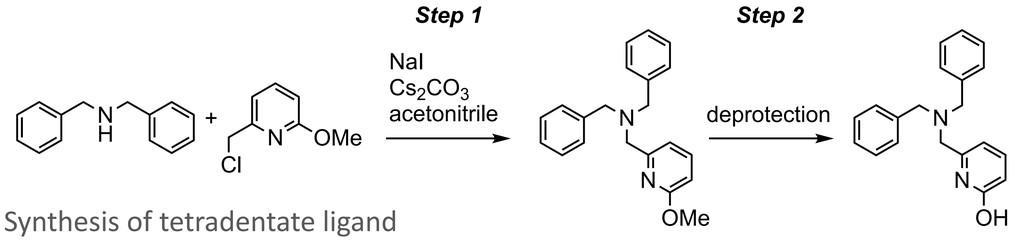
- Reactions between iron complex and catalytic ligands did not produce desired products (Scheme 5)



Scheme 5. Attachment of catalytic ligand to precursor iron complex

- Hydroxy catalytic ligand (X = OH) was not soluble in acetonitrile or acetone and the reaction did not proceed
- Attachment of methoxy catalytic ligand (X = OMe) was inconclusive due to paramagnetic impurities

Synthesis of Tetradentate Ligand

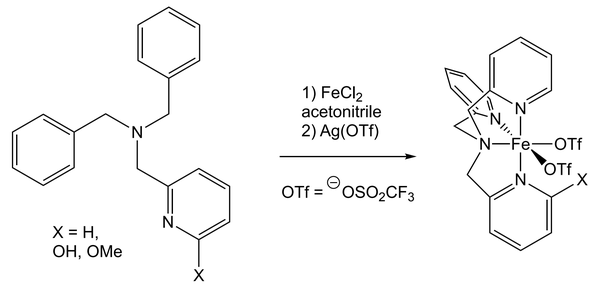


Scheme 6. Synthesis of tetradentate ligand

- Step 1 was successfully modeled after the literature procedure for the synthesis of trispicolylamine
- Step 2 was not found in the literature
- Three different methods were attempted for the deprotection step (Step 2)
- Deprotection of hydroxy group was successful using 4:1 acetic acid/HBr

Tetradentate Ligand Attachment to Iron

- Tested two methods for attaching tetradentate ligand onto iron, both were modeled after literature syntheses
- NMR test results for method 1 were inconclusive
- Inclusion of methoxy and hydroxy functional groups caused paramagnetic or other impurities that resulted in an increase in peaks



Scheme 7. Method 1 for tetradentate ligand attachment

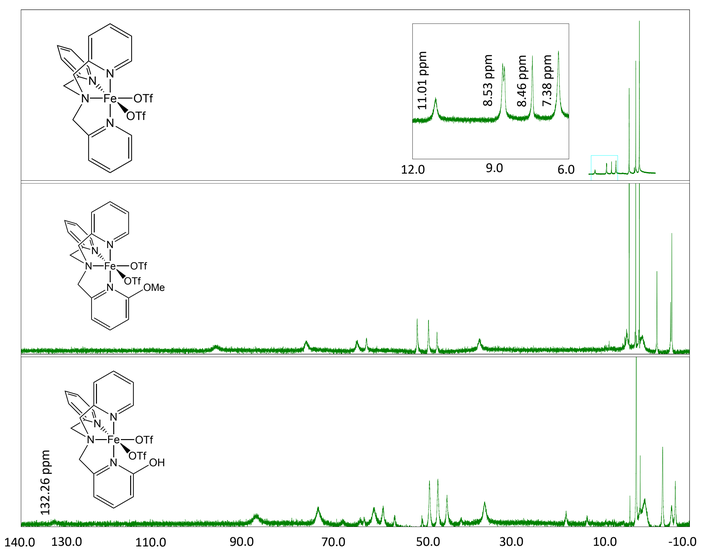
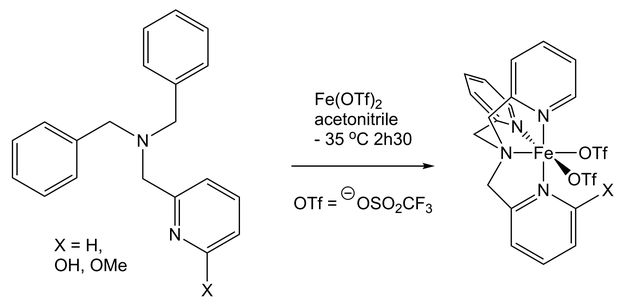


Figure 2. Method 1 for tetradentate ligand attachment, (top = H, middle = OMe, bottom = OH)



Scheme 8. Method 2 for tetradentate ligand attachment

- NMR test results for method 2 were inconclusive
- Inclusion of catalytic ligands caused paramagnetic or other impurities that resulted in unclear NMR spectra

Conclusions and Future Work

- Bipyridine and catalytic bidentate ligand attachments were unsuccessful
- Future work may study alternate methods for attaching the hydroxy catalytic ligand, such as using a protected methoxy version which may improve solubility
- The effects of different solvents on the formation of the tetradentate ligand iron complex should be studied, as well as how that affects attempts at hydrogenation chemistry
- Paramagnetic impurities resulted in inconclusive NMR spectra that impaired the ability to analyze and identify desired products throughout the research
- Characterizing compounds using X-ray crystallography in the future may provide clearer data as it is not affected by paramagnetic compounds

Acknowledgements

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Citations

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